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**Schulze et al.**

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- (54) **ELECTROSURGICAL INSTRUMENT WITH CLOSING TUBE FOR CONDUCTING RF ENERGY AND MOVING JAWS**
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- (52) **U.S. Cl.** ..... **606/51**; 606/41; 606/37
- (58) **Field of Search** ..... 606/34, 37, 39, 606/40, 41, 50, 51, 52

- 5,527,313 A 6/1996 Scott et al.
- 5,531,744 A 7/1996 Nardella et al.
- 5,569,274 A 10/1996 Rapacki et al.
- 5,573,534 A 11/1996 Stone
- 5,573,535 A 11/1996 Viklund
- 5,665,085 A 9/1997 Nardella
- 5,665,100 A 9/1997 Yoon
- 5,667,480 A 9/1997 Knight et al.
- 5,695,514 A 12/1997 Chin
- 5,709,224 A 1/1998 Behl et al.
- 5,709,680 A 1/1998 Yates et al.
- 5,713,896 A 2/1998 Nardella
- 5,722,934 A 3/1998 Knight et al.
- 5,725,479 A 3/1998 Knight et al.
- 5,766,166 A 6/1998 Hooven
- 5,772,576 A 6/1998 Knighton et al.
- 5,776,128 A 7/1998 Eggers
- 5,792,139 A 8/1998 Chambers et al.
- 5,797,938 A 8/1998 Paraschac et al.
- 5,797,941 A 8/1998 Schulze et al.
- 5,797,947 A 8/1998 Mollenauer
- 5,800,449 A 9/1998 Wales
- 5,810,128 A 9/1998 Eriksson et al.

(List continued on next page.)

- (56) **References Cited**
- U.S. PATENT DOCUMENTS**
- 2,002,594 A 5/1935 Wappler et al.
- 3,844,272 A 10/1974 Banko
- 4,052,980 A 10/1977 Grams et al.
- 5,013,312 A 5/1991 Parins et al.
- 5,324,278 A 6/1994 Eggers
- 5,324,289 A 6/1994 Eggers
- D349,341 S 8/1994 Lichtman et al.
- D350,606 S 9/1994 Koros et al.
- 5,373,840 A 12/1994 Knighton
- 5,403,312 A 4/1995 Yates et al.
- 5,443,463 A 8/1995 Stern et al.
- 5,445,638 A 8/1995 Rydell et al.
- 5,456,684 A 10/1995 Schmidt et al.
- 5,458,598 A 10/1995 Feinberg et al.
- 5,462,546 A 10/1995 Rydell
- 5,484,436 A 1/1996 Eggers et al.

**FOREIGN PATENT DOCUMENTS**

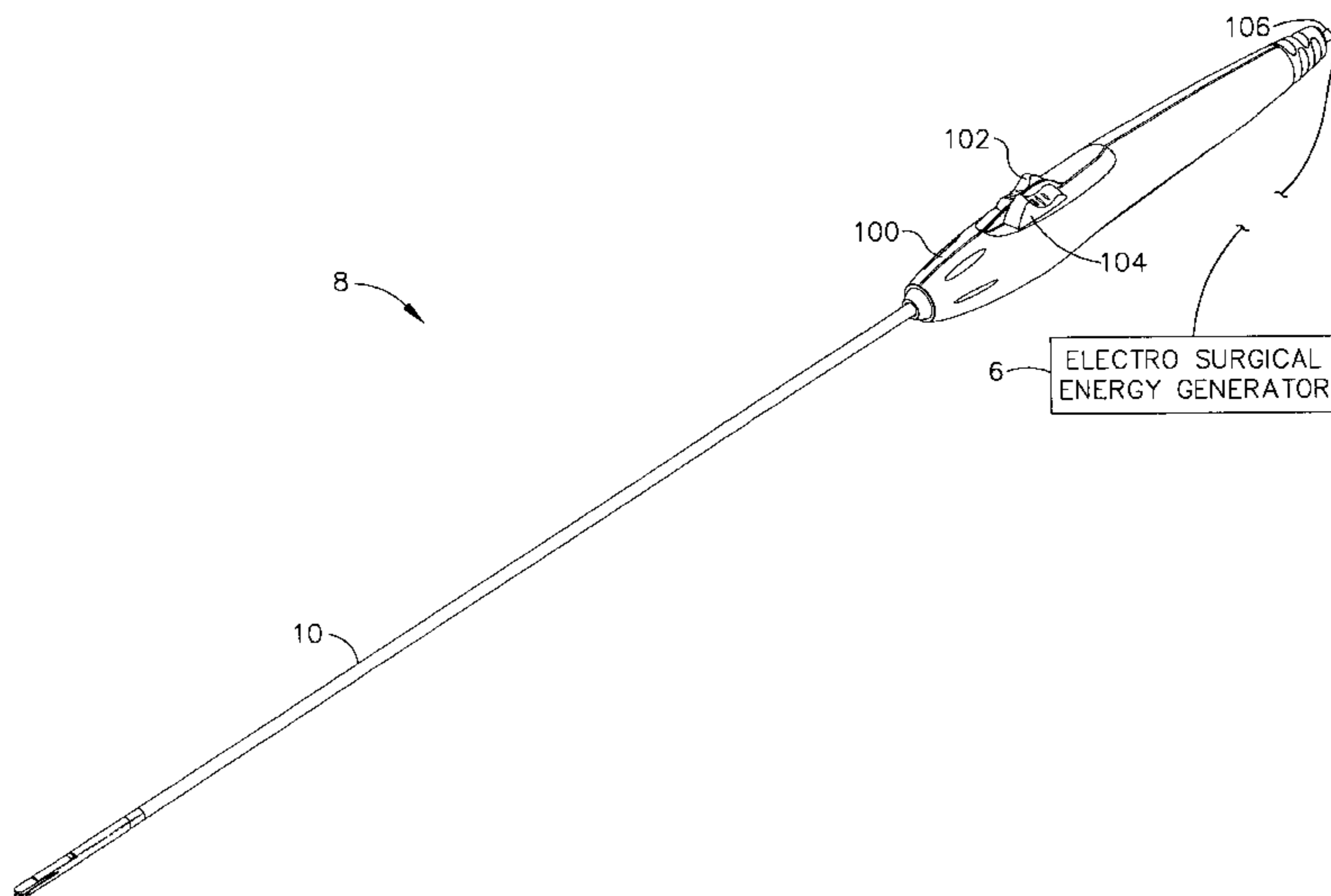
- WO WO 99/12487 3/1999
- WO 99/12487 3/1999
- WO WO 99/66850 12/1999
- WO 99/66850 12/1999
- WO WO 00/15116 3/2000
- WO WO 00/18303 4/2000

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(57) **ABSTRACT**

A bipolar electrosurgical instrument useful in harvesting blood vessels such as veins and arteries. The instrument has a pair of jaws and a central cutting element displaceable distally and proximally to dissect tissue contained between the jaws. The instrument has offset electrodes.

**20 Claims, 10 Drawing Sheets**



U.S. PATENT DOCUMENTS

5,810,808 A	9/1998	Eggers	5,925,045 A	7/1999	Reimels et al.
5,817,013 A	10/1998	Ginn et al.	5,926,138 A	7/1999	Knight et al.
5,826,776 A	10/1998	Schulze et al.	5,928,135 A	7/1999	Knight et al.
5,827,279 A	10/1998	Hughett et al.	5,928,138 A	7/1999	Knight et al.
5,833,690 A	11/1998	Yates et al.	5,951,549 A	9/1999	Richardson et al.
5,836,945 A	11/1998	Perkins	5,954,720 A	9/1999	Wilson et al.
5,853,417 A	12/1998	Fogarty et al.	6,030,384 A	2/2000	Nezhat
RE36,043 E	1/1999	Knighton	6,039,733 A	3/2000	Buysse et al.
5,860,975 A	1/1999	Goble et al.	6,056,746 A	5/2000	Goble et al.
5,891,140 A	4/1999	Ginn et al.	6,059,782 A	5/2000	Novak et al.
5,891,141 A	4/1999	Rydell	6,066,137 A	5/2000	Greep
5,913,866 A	6/1999	Ginn et al.	6,086,586 A	7/2000	Hooven
5,921,984 A	7/1999	Sutcu et al.	6,113,598 A	7/2000	Baker
5,922,001 A	7/1999	Yoon	6,126,658 A	10/2000	Baker
			6,162,220 A	12/2000	Nezhat

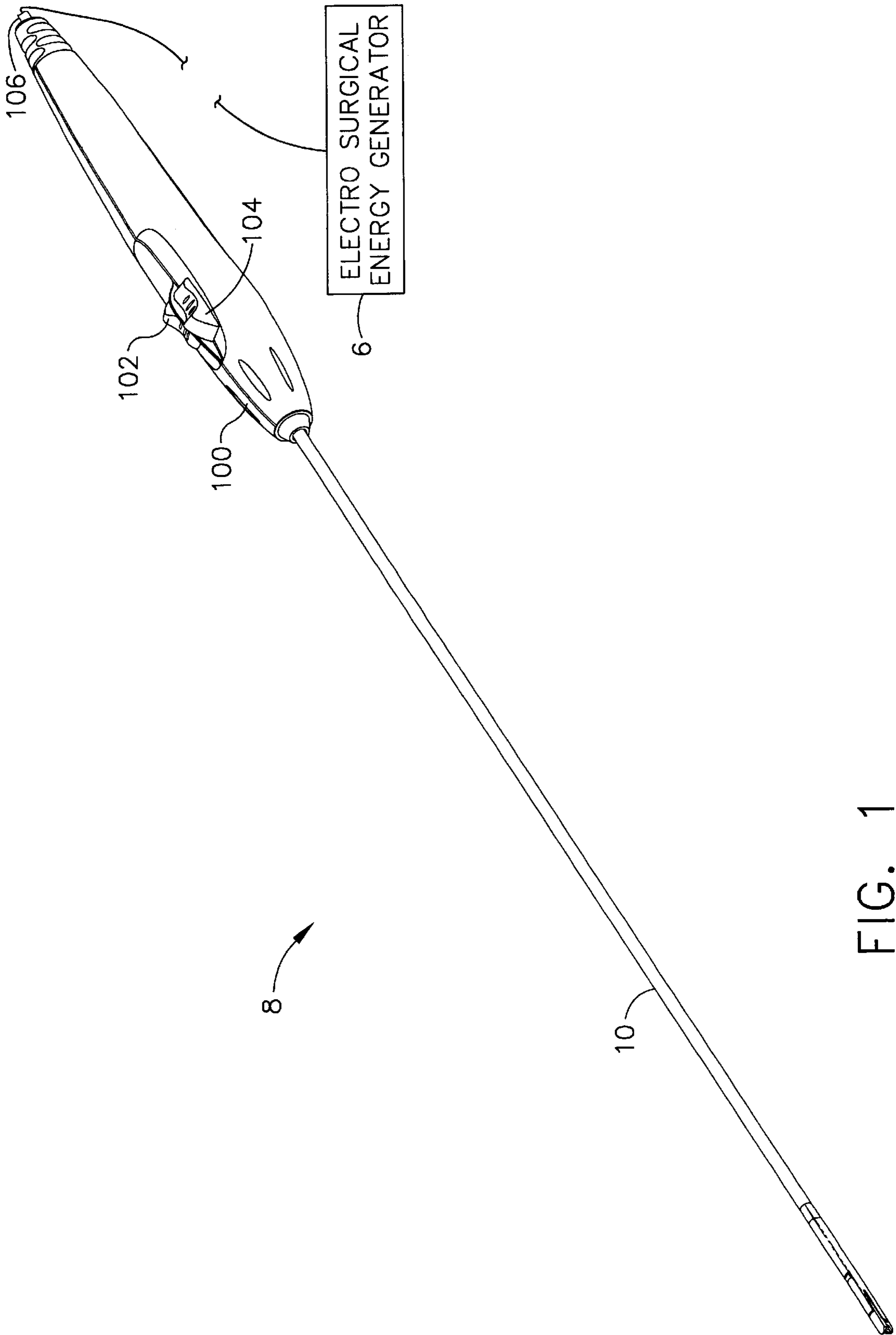


FIG. 1

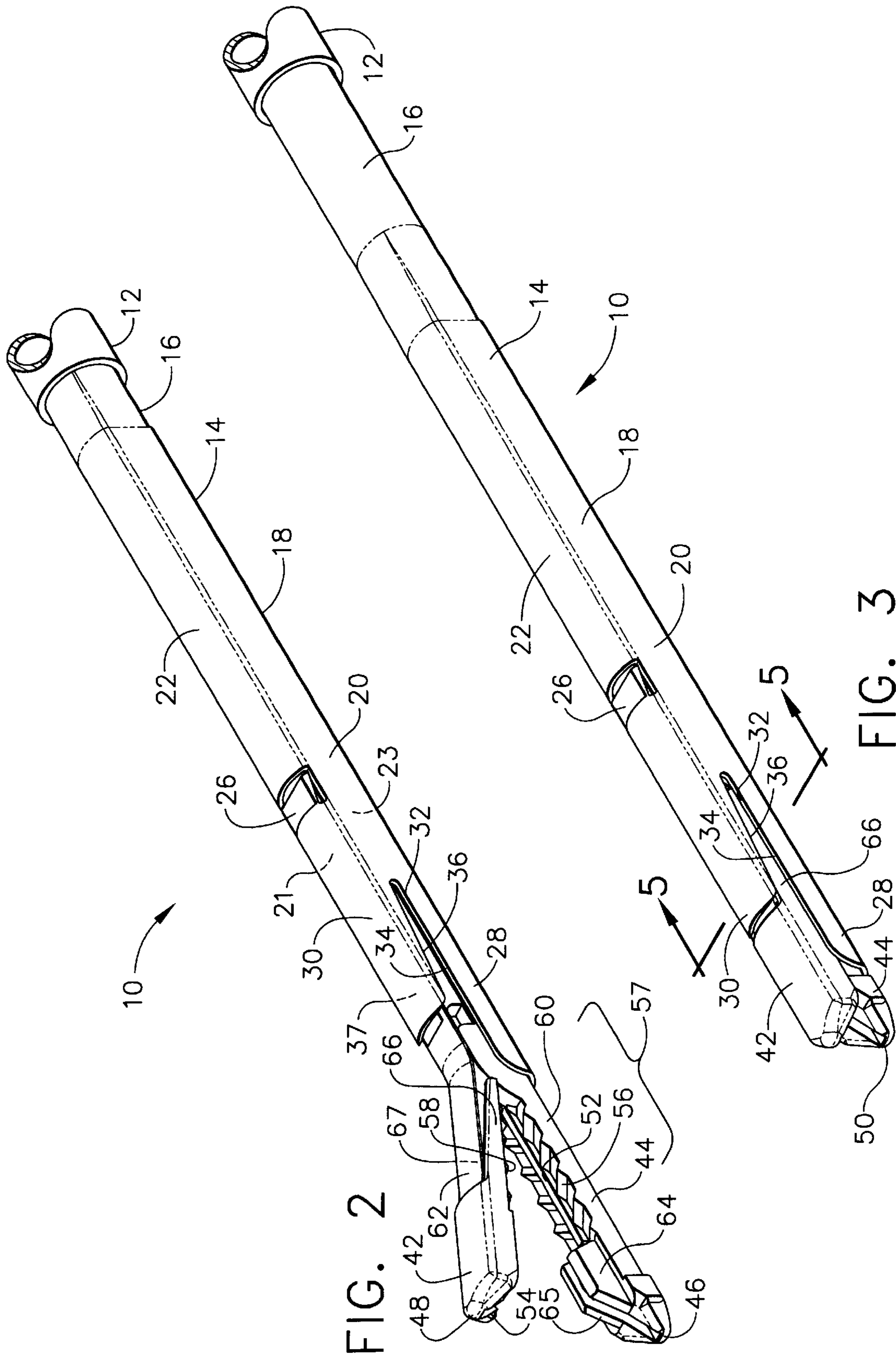


FIG. 2

FIG. 3

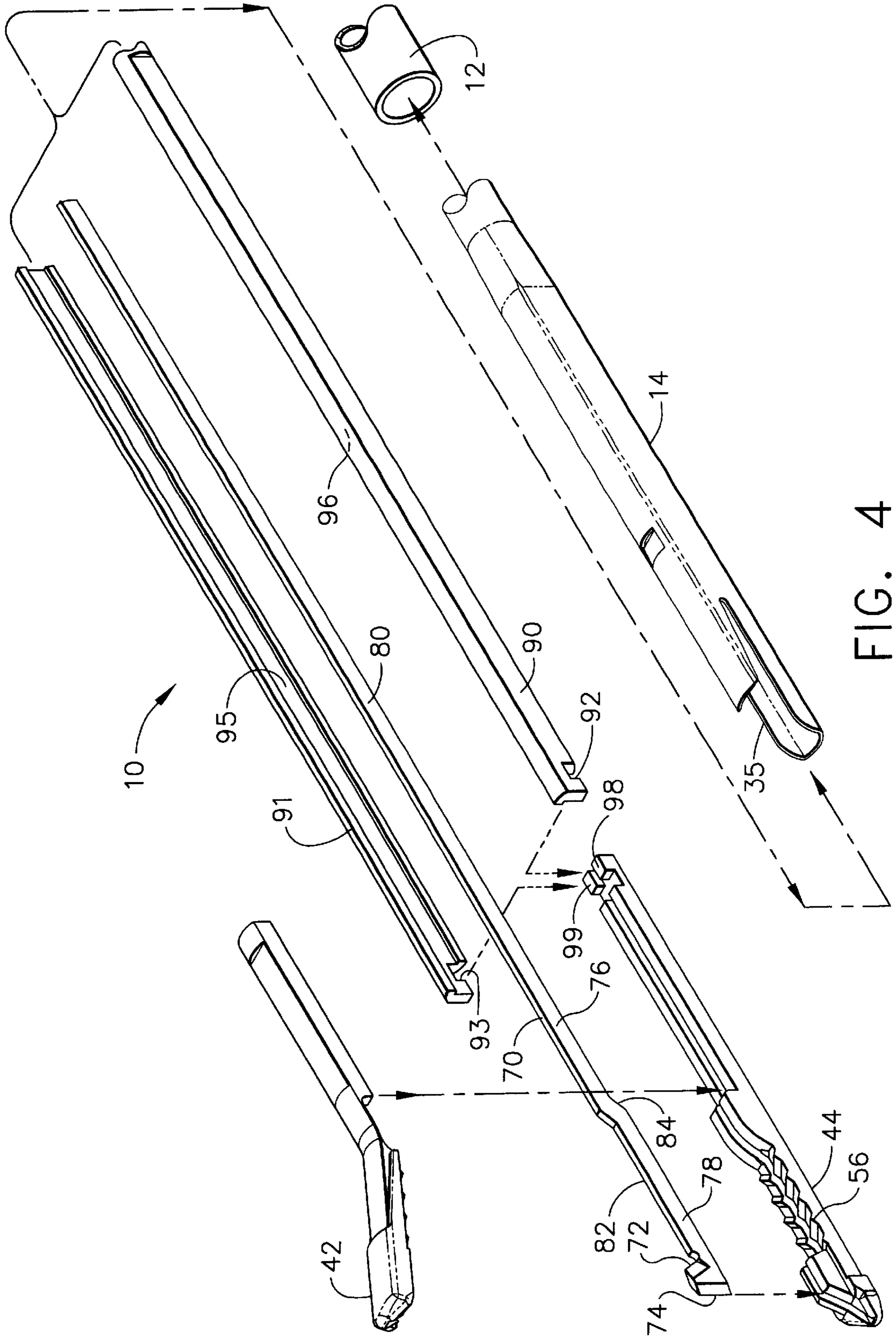


FIG. 4

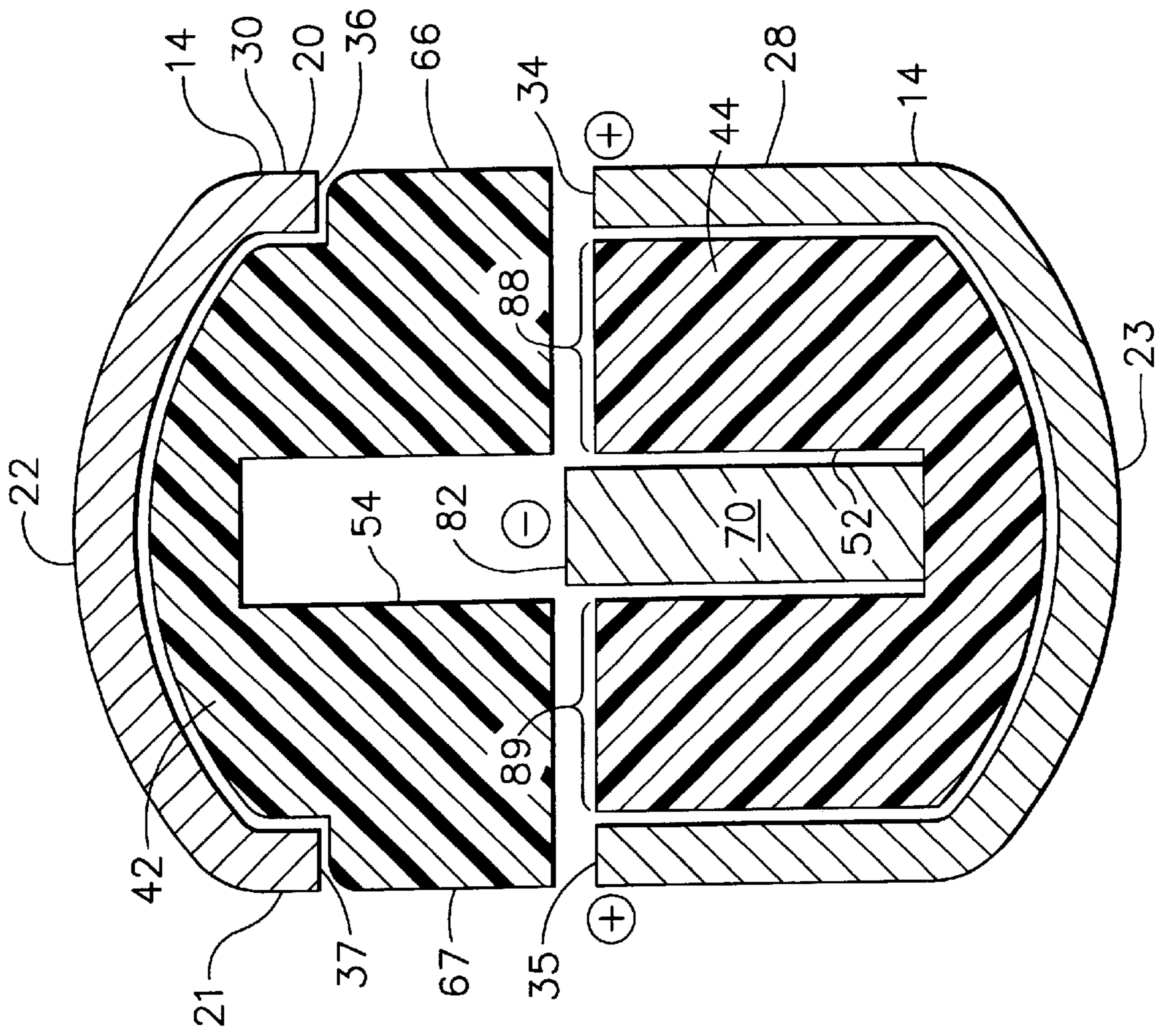


FIG. 5

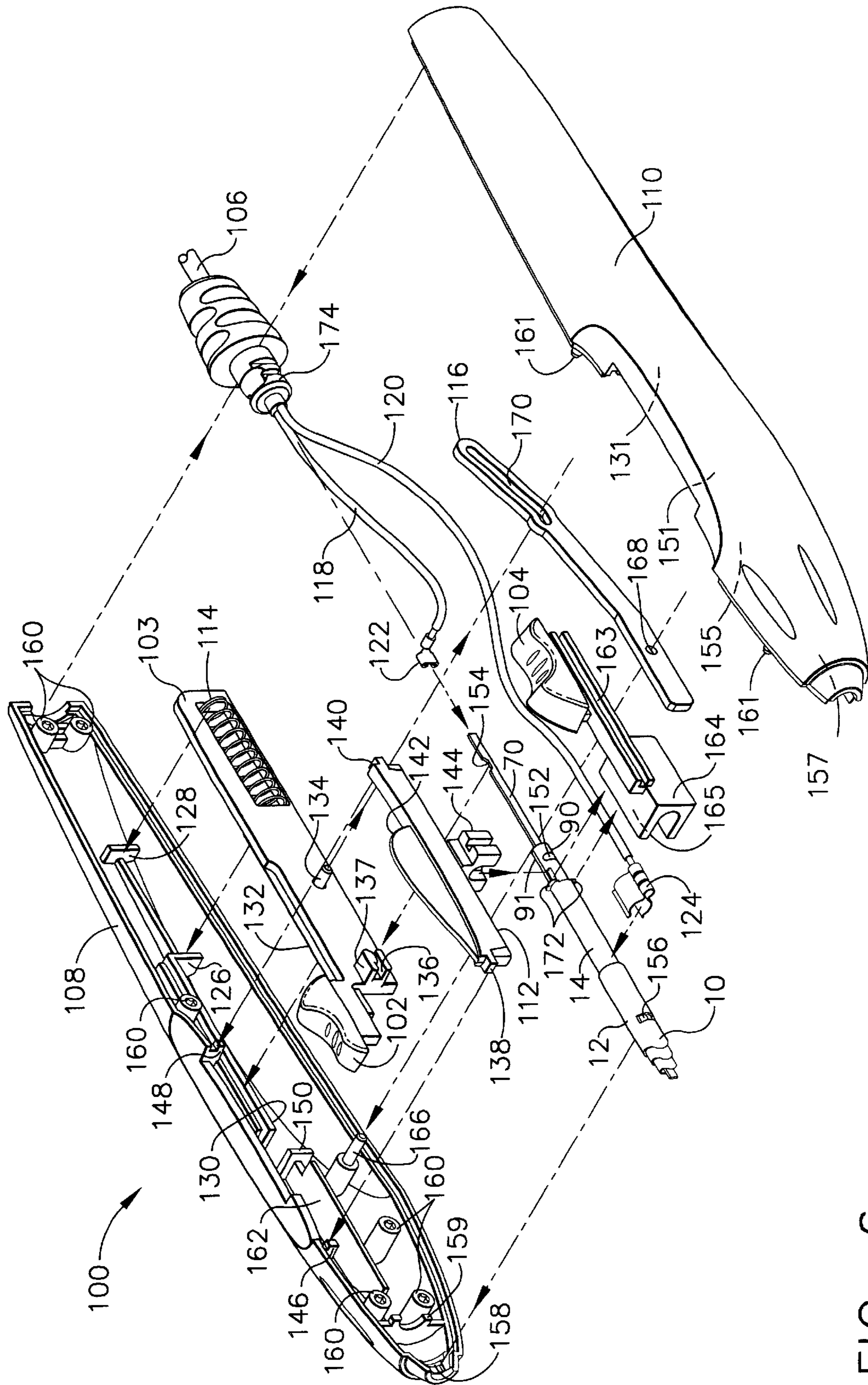


FIG. 6

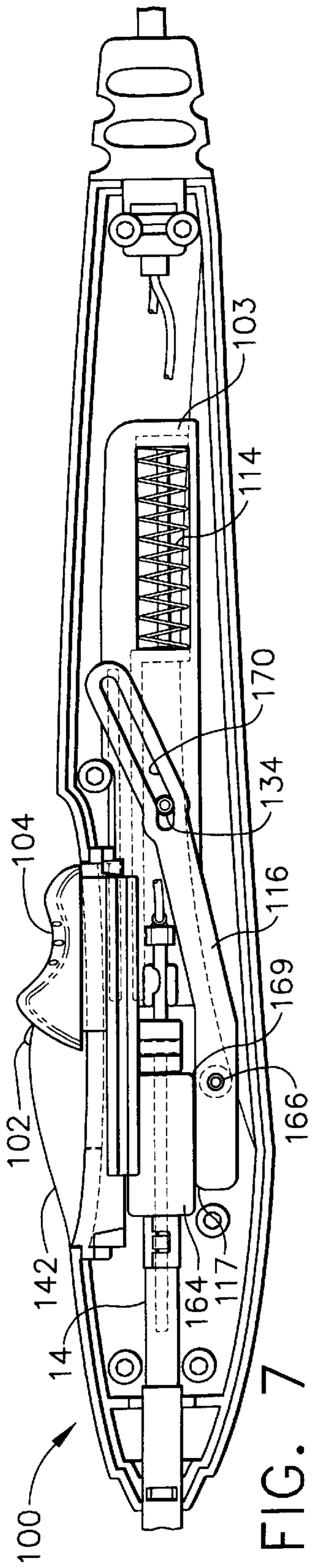


FIG. 7

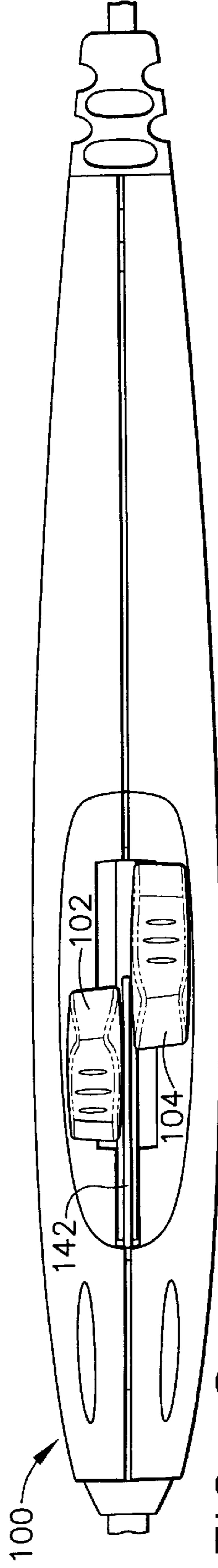


FIG. 8

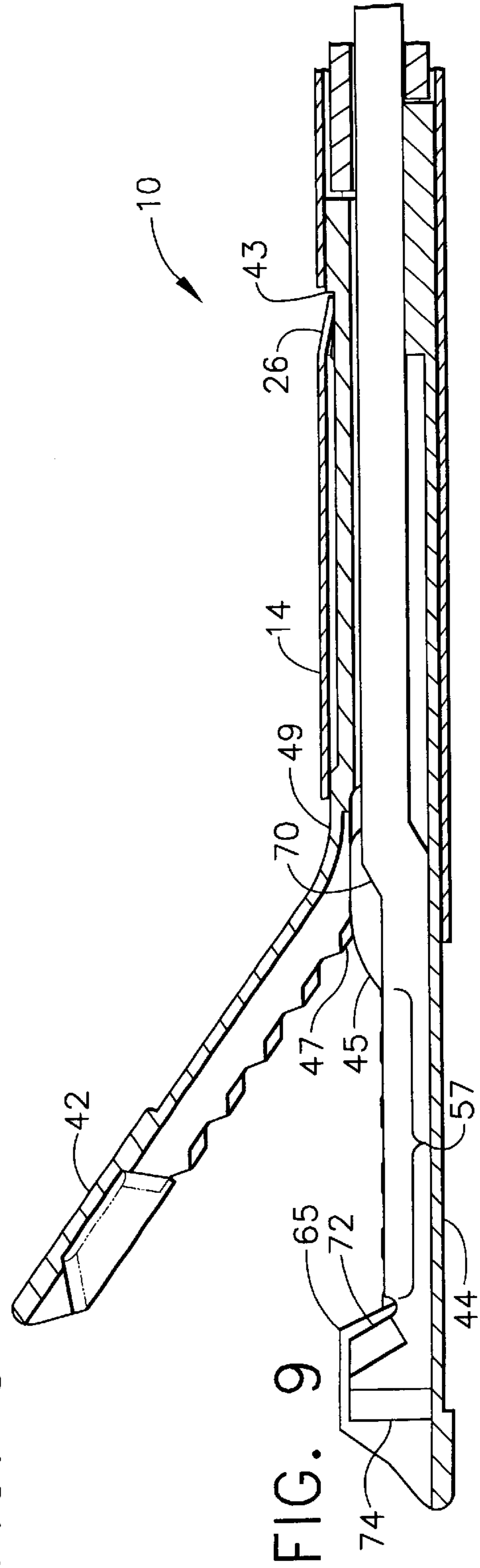


FIG. 9



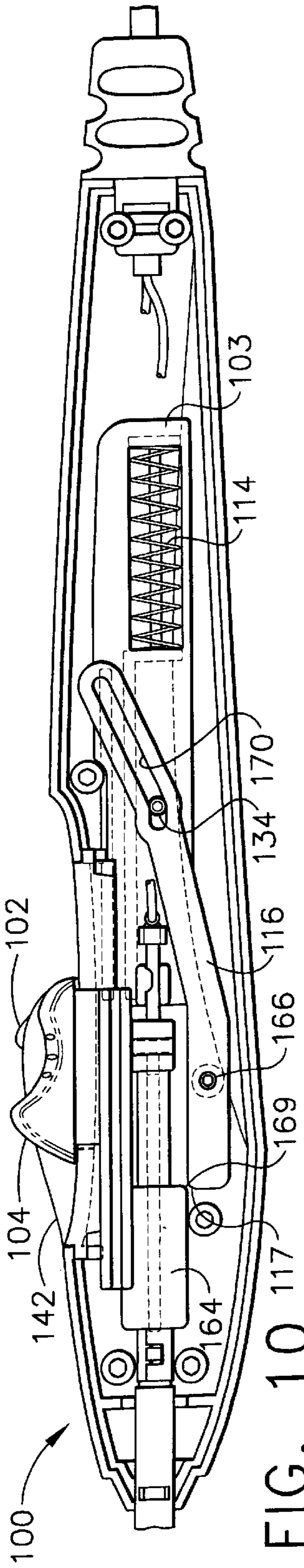


FIG. 10

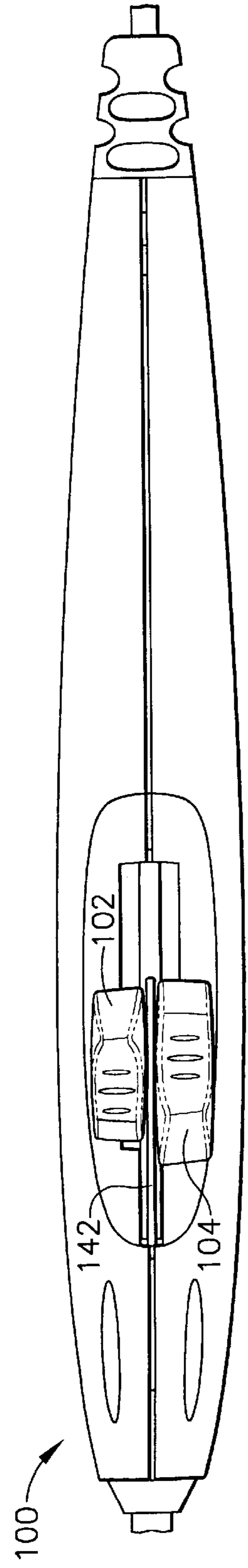


FIG. 11

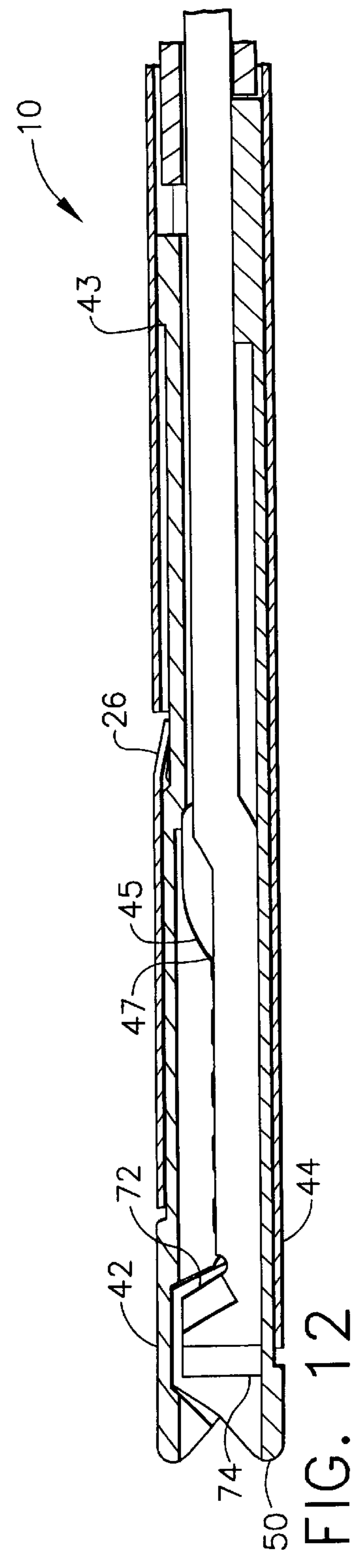
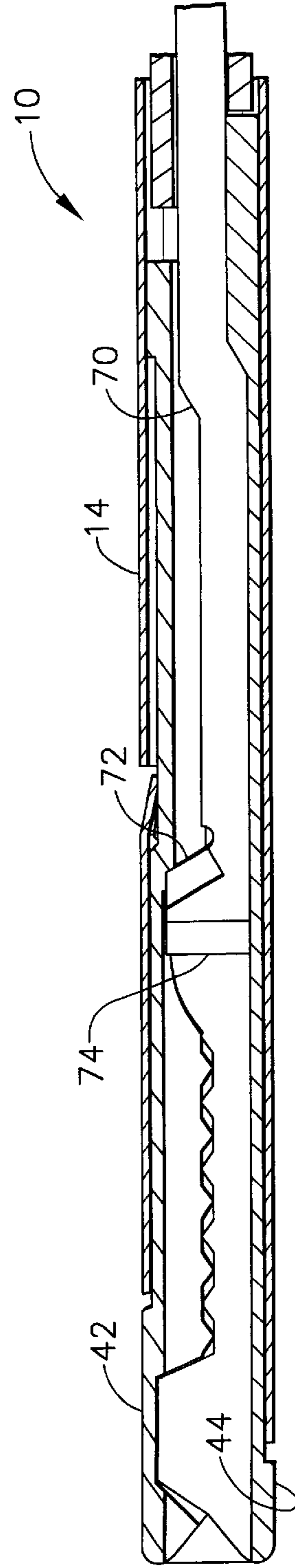
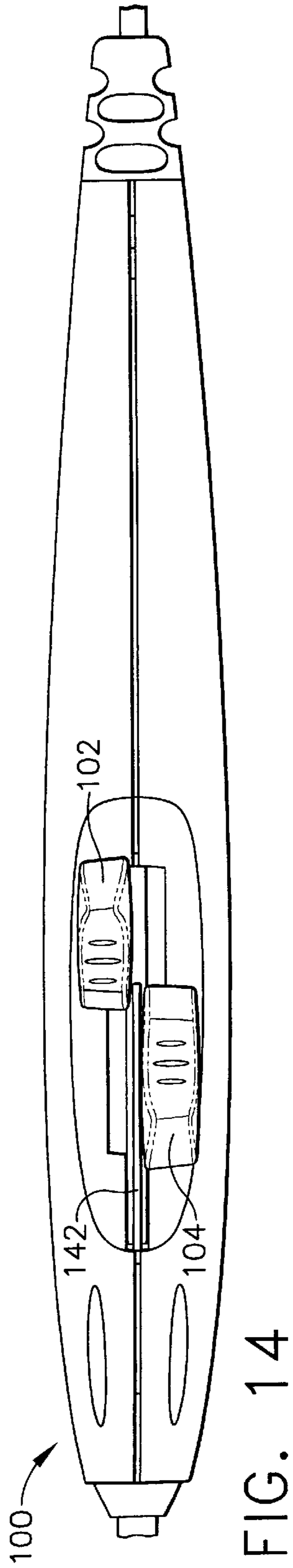
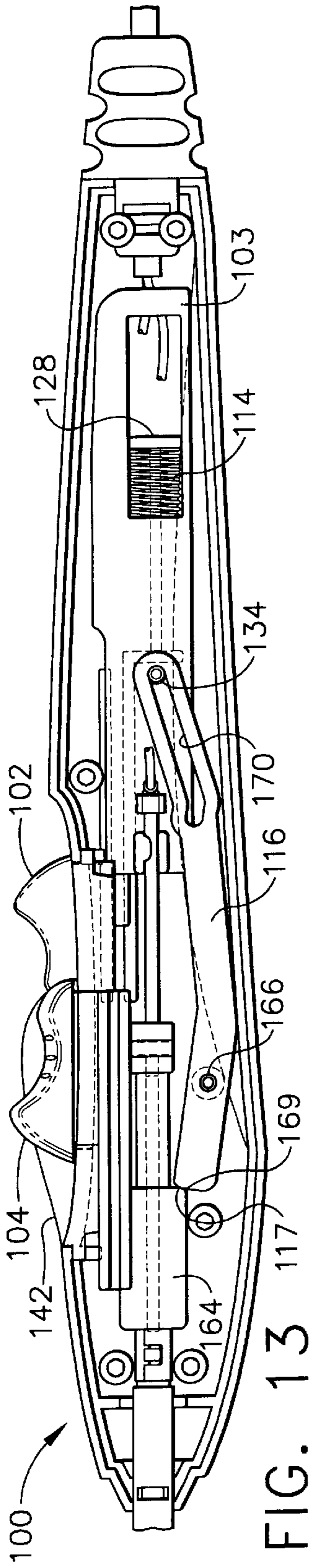
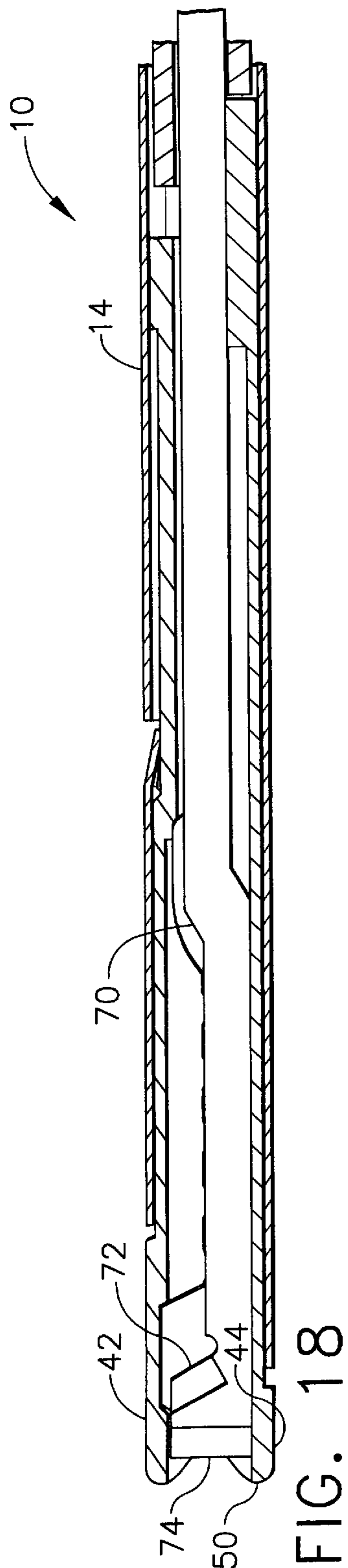
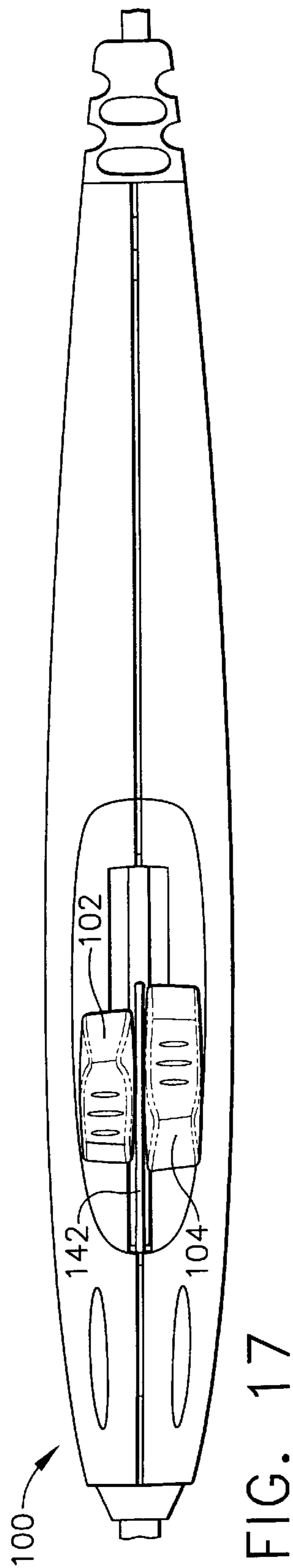
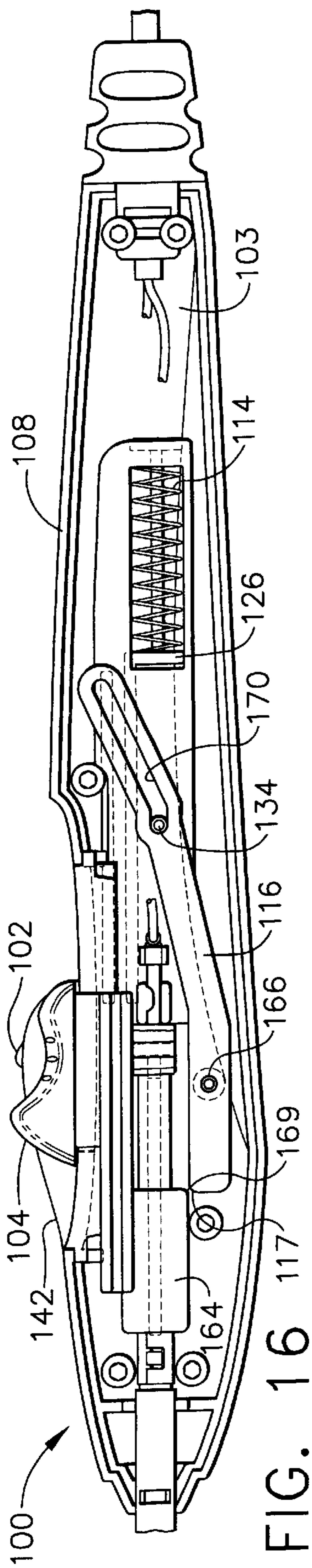


FIG. 12





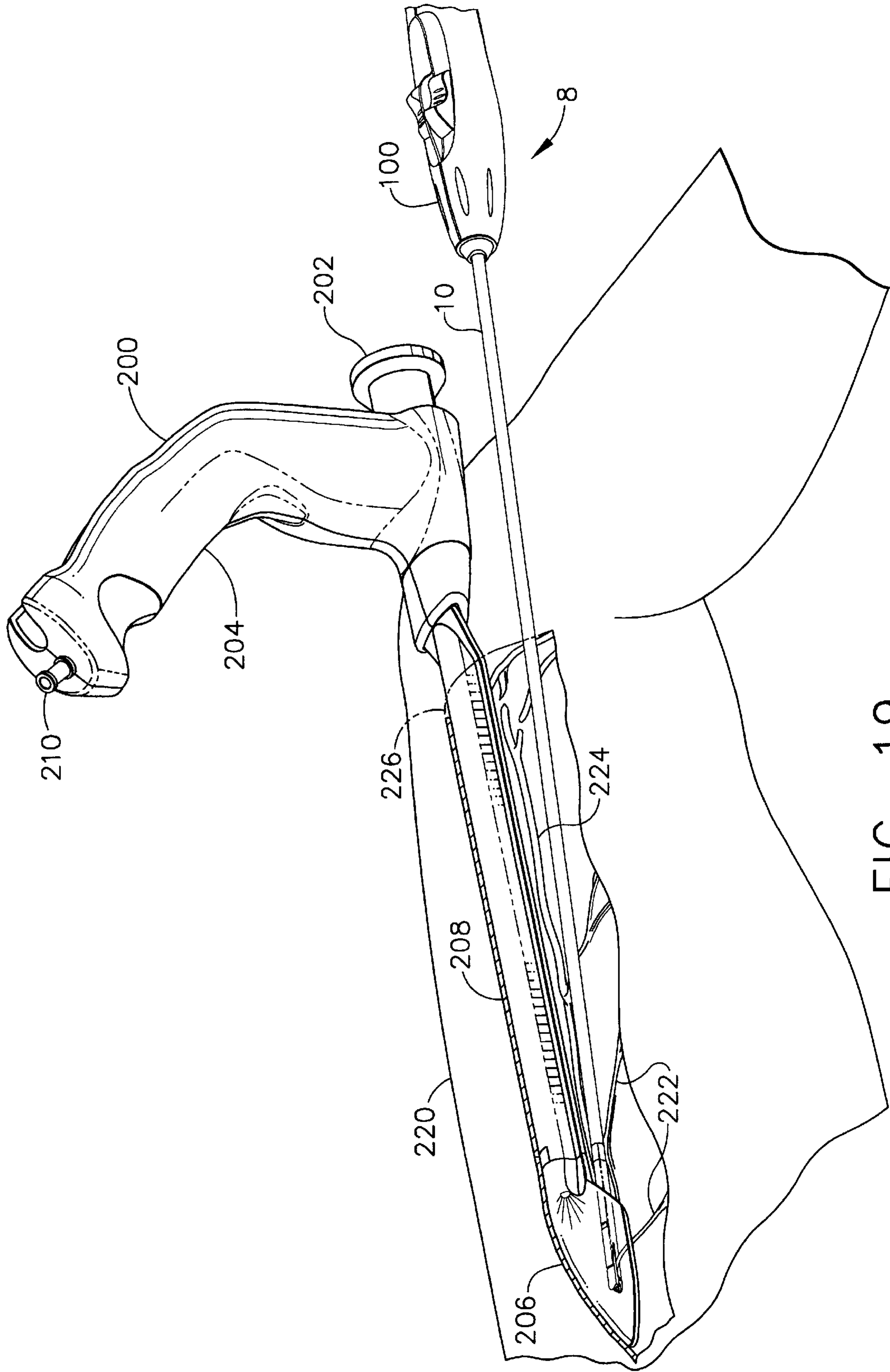


FIG. 19

## ELECTROSURGICAL INSTRUMENT WITH CLOSING TUBE FOR CONDUCTING RF ENERGY AND MOVING JAWS

### FIELD OF THE INVENTION

The present invention relates, in general, to bipolar electrosurgical instruments and, more particularly, to bipolar electrosurgical instruments incorporating offset electrodes.

### BACKGROUND OF THE INVENTION

Surgeons and surgical assistants have been using medical devices incorporating radio frequency (RF) electricity for many years to cauterize and coagulate bodily tissues during surgical procedures. Two types of RF surgical devices are conventionally utilized: mono-polar and bipolar. Both incorporate a pair of conductors for transmission of alternating RF electricity. In a mono-polar electrosurgical instrument, a first conducting electrode having a first polarity is typically placed on the patient's skin and communicates through the body, i.e. forms a conductive path, with a second conducting electrode having the opposite polarity located on the surgical instrument. A bipolar electrosurgical instrument, however, typically incorporates both first and second electrodes of opposite polarity in the same surgical instrument, substantially restricting the flow path of electric current to tissue that is contained between the electrodes. As mentioned previously, both mono-polar and bipolar electrosurgical instruments apply RF energy through tissue. The energy is dissipated within the tissue in the form of heat due to the natural impedance of tissue. As the temperature of the tissue rises, the electrical resistivity of the tissue increases. When RF energy is applied to tissue, and as the temperature reaches about 67–70 degrees Celsius, the tissue begins to coagulate. As increasing amounts of energy dissipate in the tissue, the collagen forming the tissue matrix breaks down and appears to "melt". Mechanical compression of the coagulating tissue layers fuses and seals any contained blood vessels, so that the tissue may be cut without bleeding. When the tissue temperature reaches 100 degrees C., most fluids (including water) vaporize into the surrounding tissues and air.

The energy dissipation rate in tissue depends on numerous factors, including the inherent electrical resistivity of the tissue and the electrical current density. Electrical current density in various tissues is an important consideration in the design of the electrodes in a bipolar electrosurgical instrument, including the number, size, shape, and placement of the electrodes.

Many surgeons prefer to use bipolar electrosurgical instruments for hemostatically (without bleeding) sealing tissue prior to transection. Bipolar electrosurgical devices are known for grasping, coagulating, and cutting tissue. Typically the instruments have grasping elements, and one of the grasping elements is an electrically opposite pole of the other grasping element. For this type of conventional, bipolar electrical configuration, electrical current can be simplistically thought of as "flowing" from one grasping element (a positive pole), through the grasped tissue, and to the other grasping element (a negative pole). When tissue held between the grasping elements is coagulated, it is known that the electrical resistivity of that portion or zone of tissue increases dramatically. This causes the electrical current to seek a new path of lesser electrical resistivity around the zone, resulting in a spread to tissue adjacent to the outside of the grasping elements. Accordingly, it is believed that the zone of coagulated tissue continues to increase

laterally from the grasping elements. The final width of the coagulation zone depends on several factors, including the power setting of the electrosurgical generator, and on the length of time the operator applied electrical energy to the tissue. etc. It is typical for an operator to apply electrical energy (usually by stepping on a foot actuator) for several seconds more than is actually needed to ensure that the grasped tissue is completely coagulated prior to cutting to prevent bleeding. If the amount of tissue grasped is very small, coagulation of the grasped tissue may occur so quickly that the operator cannot stop the application of electrical energy quickly enough to prevent excessive lateral spreading of the coagulation zone. In addition, the operator may not always be able to visualize the spreading of the coagulation zone because of obstructing tissue structures, especially during an endoscopic procedure; or, because the coagulation of the tissue occurs on the inside of the tissue or blood vessel.

Excessive lateral spread of the coagulation zone may be harmful to patients undergoing surgical procedures in which an organ or vessel is harvested for use in the same or a different patient. For example, in a coronary artery bypass graft (CABG) procedure, a surgeon or surgical assistant may remove a saphenous vein from one of the patient's legs to use as one or more bypass grafts on that patient's heart. In recent years, new surgical dissecting/retracting tools have been introduced to enable the surgical operator to harvest the saphenous vein endoscopically. Examples of endoscopic vessel harvesting devices and methods are contained in the following U.S. Patents, which are incorporated by reference: U.S. Pat. No. 5,667,480; 5,722,934; 5,928,135; and 5,928,138. In such surgical procedures the operator "tunnels" with the surgical dissecting/retracting tool alongside the vein under the skin, working through a small incision made into the inside of the patient's leg or knee. The benefits of this procedure to the patient are numerous because endoscopic vein harvesting (EVH) results in greatly reduced recovery time and pain for the patient as compared to the earlier open procedure of creating an incision along the leg equal to the length of the vein harvested. In addition scarring is limited, and the incidence of serious infections reduced.

In conventional EVH procedures, the surgical operator uses the surgical dissecting/retracting tool to create a small working space at the distal end of the tool and adjacent to the vein being harvested. As the operator maneuvers the tool along the vein to separate the vein from adjacent tissues, the operator typically encounters numerous smaller collateral vascular side branches of the main vein (usually about 15). To harvest the main vein with minimal bleeding of surrounding tissues, the operator may apply at least two conventional surgical clips to each side branch encountered, using a conventional mechanical endoscopic surgical clip applier. Then the clip applier is removed, an endoscopic scissors is inserted to cut the side branch between the applied clips. Each instrument insertion and removal is not only time-consuming, but care must be taken not to cause trauma to the vein being harvested and to surrounding tissues in the leg. The operator may also use bipolar electrosurgical scissors in place of mechanical clip appliers, which are well known in the art for use in this type of surgical procedure. However, bipolar scissors may induce undesirable lateral spreading of the coagulation zone if not used correctly, and the experience of the operator is crucial in preventing injury to a harvested vein to be used in the CABG procedure. When using bipolar scissors or any of the other conventional electrosurgical instruments during an EVH procedure, the operator is required to treat each side branch at a location as

far distant laterally from the main vein as practical, and the operator must apply RF energy for a minimal time to seal the side branch for cutting.

Various embodiments of a relatively new kind of bipolar, electro-surgical device are disclosed in the following patents hereinafter referred to collectively as the "offset electrode device", and are incorporated by reference herein: U.S. Pat. Nos. 5,403,312; 5,709,680; and 5,833,690. In the offset electrode device, the bipolar electrodes have an "offset" configuration and coagulation of tissue is substantially confined to only the tissue held between a pair of interfacing surfaces. The offset electrode devices also provide for high tissue compression to coagulate tissue uniformly and to force fluid out of the coagulation zone. Such fluid would vaporize during coagulation and shoot laterally from the interfacing surfaces, possibly causing thermal injury to adjoining tissue. The offset electrode devices disclosed, however, in the references patents are not specifically adapted for use in endoscopic vein harvest procedures or in other types of minimally invasive surgical procedures requiring 5 mm diameter endoscopic ports. There is a need in this art for an offset electrode, bipolar electro-surgical instrument that may be used through a five millimeter trocar port, and that has minimally sized jaws for improved access and visualization of tissue structures in the surgical site.

Another concern of the surgical operator when using any electro-surgical instrument is the tendency of coagulated tissue to stick to the jaws of the instrument during operation of the instrument. The operator must take additional time to manipulate the instrument to release tissue adhering to the end effectors, possibly injuring surrounding tissue, especially when operating in limited working spaces during endoscopic procedures. Adhering tissue also reduces the electrical conductivity of the bipolar electrodes and it is often necessary for the operator to manually clean the electrodes in order to continue using the instrument. This is especially prevalent for forceps-type grasping instruments incorporating the conventional bipolar electrode (non-offset) configuration.

Many conventional surgical instruments incorporate cutting blades for transecting tissue held within the jaws. A potential difficulty with cutting blades of such instruments is "tissue-tagging" when the blade does not completely cut through all the tissue held in the jaws. This may occur, for example, if the cutting edge of the blade is dull or nicked. Another reason tissue-tagging may occur, or even some bleeding after the tissue is coagulated and cut, is that the tissue is not held firmly enough within the jaws of the instrument as the cutting blade is passed through the tissue held. When tissue is initially clamped within the jaws of the instrument, the clamping force may be very high due to the elasticity of the fluid-containing tissue. But after the tissue has been compressed for a period of time, and then is coagulated, most of the fluid has been driven out of the tissue, with the result that the elasticity of the tissue is greatly reduced. The clamping force on the tissue is also decreased so that the tissue may shift within the jaws as a cutting blade is passed through it. This presents the possibility that not all the tissue will be cut, or the cutting blade will pass through a portion of tissue that is not fully coagulated.

During some surgical procedures, including the EVH procedure, the surgical operator must cut and dissect a first tissue structure away from a second tissue structure prior to performing a transection or other surgical procedure on the second tissue structure. A conventional technique for this type of surgical cutting and dissecting used a pair of

conventional, mechanical scissors held in an open configuration, thus forming a vee-shape with the scissors blades. The scissors blades are then advanced between the first and second tissue structures to cut and separate them. At this point, the surgical operator may remove the scissors and continue the surgical procedure with another surgical instrument such as a clip applier for ligation of the second tissue structure. During an EVH procedure, the exchange of endoscopic mechanical scissors and the clip applier in and out of the working space may occur many times, increasing the time to perform the procedure, and possibly injuring the vein or surrounding tissue. An alternative to using a mechanical scissors together with a clip applier is to use a bipolar electro-surgical scissors as described previously. Using conventional bipolar coagulation and cutting devices may result in excessive lateral spreading of the thermally affected zone of tissue, especially if the operator is inexperienced or otherwise not careful.

Another shortcoming when using currently available electro-surgical cutting instruments with cutting blades is that the cutting blade may be exposed accidentally to adjacent tissue when the operator does not intend to cut the tissue.

Accordingly, what is needed in this art is a bipolar electro-surgical instrument incorporating offset electrodes and compression zones, as described for the offset electrode device, yet improved to be less surgically invasive and to provide better access and visualization at the surgical site. There is also a need for a bipolar electro-surgical instrument that easily releases tissue from the jaws after each cycle of use, and automatically wipes electrode surfaces clean for each cycle of use. Additionally, there is a need for an instrument having more than one cutting blade that cuts through the tissue held within the jaws to improve the probability of completely transecting the tissue held, but without increasing the size or cost of the instrument. There is also a need for an instrument that provides for additional clamping force to be applied to tissue held in the jaws immediately prior to passing a cutting blade through the tissue. There is yet a further need for an instrument that safely coagulates tissue without excessive lateral thermal spread, and which reduces the need for using mechanical scissors and clip appliers during a surgical procedure. Replacing a scissors and a clip applier with a single bipolar electro-surgical cutting instrument, for example, and reducing surgery time by reducing the number of instrument exchanges during the surgical procedure, allows a significant cost savings to the hospital, and is beneficial to the patient. There is also a need for an electro-surgical instrument with a cutting blade that has an operational sequencing element that allows the movement of the cutting blade through a tissue grasping region only when the jaws are fully closed, thus reducing the possibility of accidentally injuring the patient.

#### SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a bipolar electro-surgical instrument incorporating offset electrodes and compression zones, that is less surgically invasive and that provides better access and visualization at the surgical site.

It is another object of the present invention to provide a bipolar electro-surgical instrument that easily releases tissue from the jaws after each cycle of use, and automatically wipes electrode surfaces clean for each cycle of use.

It is yet another object of the present invention to provide an instrument having more than one cutting blade that cuts

through the tissue held within the jaws to improve the probability of completely transecting the tissue held, but without increasing the size or cost of the instrument.

It is still yet another object of the present invention to provide an instrument that provides for additional clamping force to be applied to tissue held in the jaws immediately prior to passing a cutting blade through the tissue.

Yet another object of the present invention is to provide an instrument that safely coagulates tissue without excessive lateral thermal spread, and which reduces the need for using mechanical scissors and clip applicators during a surgical procedure.

Still another object of the present invention is to provide an electrosurgical instrument with a cutting blade that has an operational sequencing element that allows the movement of the cutting blade through a tissue grasping region only when the jaws are fully closed, thus reducing the possibility of accidentally injuring the patient.

Accordingly, a bipolar electrosurgical instrument is disclosed. The instrument has a handle. The handle has a proximal end, a distal end, an outer surface, a top, a bottom and an interior cavity. A first conductor and a second conductor are mounted to the handle. The instrument has a shaft having a distal end, a proximal end, and a longitudinal axis extending therebetween. The proximal end of the shaft is mounted to the handle. Preferably, the shaft has a lumen therethrough. A closing tube is slidably mounted to said shaft. The closing tube has a proximal end, a distal end, a longitudinal axis, and a lumen therethrough. A pair of opposed arms extending distally from the distal end of said closing tube. The arms are spaced laterally apart. There is a first electrode surface on one of said arms. The first electrode surface is in electrical contact with the first conductor and has a first polarity. A first jaw member is mounted in the distal end of said closing tube. The first jaw has a proximal end and a distal end, an outer surface and an inner surface. The proximal end of the first jaw member is mounted to the distal end of the shaft. An opposing second jaw member is mounted in the distal end of the closing tube. The second jaw member has a proximal end and a distal end, and an outer surface and an inner surface. The second jaw member is moveable relative to the lower jaw from a closed position to an open position. An elongated member is mounted in the shaft. The elongated member has a proximal end and a distal end. The elongated member is preferably slidably mounted in said shaft and movable in the jaws. The elongated member is electrically connected to the second conductor and electrically isolated from the first electrode surface. The elongated member has a second electrode surface positioned substantially parallel to and laterally offset from the first electrode surface. The second electrode surface has a second electrical polarity that is opposite of said first electrical polarity, so that bipolar electrosurgical energy may be conducted through tissue located between the first electrode surface and the second electrode surface. A first actuator is mounted in the handle. The first actuator is connected to the proximal end of the closing tube. Movement of the first actuator causes the sliding tube to move longitudinally. An optional second actuator may also be mounted in the handle. The second actuator is connected to the proximal end of the elongated member. Movement of the second actuator causes the elongated member to move longitudinally.

Yet another aspect of the the present invention is the combination of the bipolar surgical instrument of the present invention and a bipolar electrosurgical generator.

Still yet another aspect of the present invention is a method of using the bipolar electrosurgical instrument of the present invention in a surgical procedure to coagulate tissue.

The foregoing and other features and advantages of the present invention will become more apparent from the following description and accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of an electrosurgical clamping, coagulating, and cutting instrument of the present invention shown connected to a schematic of an electrosurgical energy generator.

FIG. 2 is an isometric view of the distal section of a tube assembly of the instrument of FIG. 1, shown with an upper jaw in an open position.

FIG. 3 is an isometric view of the distal section of the tube assembly of the instrument of FIG. 1, shown with the upper jaw in a closed position.

FIG. 4 is an exploded, isometric view of the distal section of the tube assembly of the instrument of FIG. 1.

FIG. 5 is a cross-sectional view of the distal portion of the tube assembly taken through View-Line 5—5 of FIG. 3.

FIG. 6 is an exploded, isometric view of a handle assembly of the instrument of the present invention.

FIG. 7 is a side view of the interior of the handle assembly of the instrument of the present invention with the left handle shell removed, illustrating the actuators in positions to maintain the upper jaw in an open position and the cutting element in a central position.

FIG. 8 is a top view of the handle assembly of FIG. 7, with the left and right handle shell assembled.

FIG. 9 is a longitudinal, sectional view of the distal section of the tube assembly of FIG. 7.

FIG. 10 is a side view of the handle assembly of the instrument of the present invention with the left handle shell removed, illustrating the actuator positioned such that the upper jaw is in a closed position and the cutting element is in a central position.

FIG. 11 is a top view of the handle assembly of FIG. 10 with the left handle shell assembled with the right handle shell.

FIG. 12 is a longitudinal, sectional view of the distal section of the tube assembly of the instrument of FIG. 10.

FIG. 13 is a side view of the handle assembly of an instrument of the present invention having the left handle shell removed, showing the actuators located to cause the upper jaw to be in the closed position and the cutting element in a proximal position.

FIG. 14 is a top view of the handle assembly of FIG. 13, with the left handle shell assembled.

FIG. 15 is a longitudinal, sectional view of the distal portion of the tube assembly of the instrument of FIG. 13.

FIG. 16 is a side view of the handle assembly of the instrument of the present invention having the left handle shell removed, showing the actuators located such that the upper jaw is the closed position and the cutting element in a distal position.

FIG. 17 is a top view of the handle assembly of FIG. 16, with the left handle shell assembled.

FIG. 18 is a longitudinal, sectional view of the distal portion of the tube assembly of the instrument of FIG. 16.

FIG. 19 is an isometric view illustrating the instrument of the present invention being used in combination with an endoscopic surgical retractor for surgically harvesting a vessel from a patient.

#### BEST MODE FOR CARRYING OUT THE INVENTION

The electrosurgical clamping, coagulating, and cutting instrument of the present invention is illustrated in FIG. 1

shown with a schematic representation of an electrosurgical energy generator 6. Instrument 8 is seen to have a handle assembly 100 and a tube assembly 10 having a distal end section and a proximal end. Handle assembly 100 is seen to be mounted to the proximal end of tube 10. Handle assembly 100 further comprises a first actuator 104, a second actuator 102, and a power cord 106 for electrical connection to electrosurgical energy generator 6. An operator actuates first actuator 104 for grasping and compressing tissue. The operator actuates second actuator 102 for cutting tissue. The operator presses a conventional foot switch (not shown) provided with electrosurgical generator 6 for supplying bipolar electrosurgical energy to instrument 8.

Instrument 8 operates with numerous conventional, commercially available, electrosurgical energy generators. An example of electrosurgical energy generator 6 is a unitary mono-polar-bipolar RF generator, such as the Valleylab "FORCE 2" RF Generator manufactured by Valleylab, a division of Tyco Healthcare Group LP, 5920 Longbow Drive, Boulder, Colo., 80301-2199, U.S.A.

Conventional power cord 106 may be long (for example, over two meters) and connect directly to electrosurgical energy generator 6 via standardized, bipolar connectors, which are well-known in the art. Power cord 106 may also be short (less than one third of a meter, for example) and have a standardized, conventional bipolar connection (also well-known in the art) to another, longer power cord, which is normally reusable and available with electrosurgical energy generator 6. An operator uses a foot-activated switch of electrosurgical energy generator 6 to supply energy through instrument 8 to the tissue being treated. The operator adjusts the maximum power setting on electrosurgical energy generator 6 to be in sufficiently effective range; for example a preferable range of approximately 20–60 watts, although instrument 8 operates at other conventional power settings also. The operator may press the foot switch and supply energy to instrument 8 for a few seconds to coagulate the tissue being treated. Only a portion (about 3 watts) of this energy is conducted through the tissue due to the high resistivity of tissue and the use of offset electrodes as described earlier and hereinafter. The operator may use instrument 8 to hemostatically seal a small (2–4 mm diameter) blood vessel, for example, in less than one second, but the operator may continue to depress the foot switch a few more seconds if desired since there is believed to be practically no additional, lateral spreading of thermal energy.

Referring now to FIG. 2, an isometric view of the distal portion or section of tube assembly 10 of FIG. 1 is illustrated. An elongated, closing tube 14 is shown retracted to an open position, holding upper jaw 42 in an open position relative to a stationary, opposing, lower jaw 44. Upper jaw 42 and lower jaw 44 are preferably injection molded from a biocompatible plastic such as polycarbonate or polyethylene or other conventional biocompatible polymeric materials. Closing tube 14 is preferably made from a stainless steel tube, although other conventional biocompatible materials may be used. The operator moves closing tube 14 in the proximal direction with respect to handle assembly 100 to open upper jaw 42 by moving first actuator 104 (see FIG. 1) in the proximal direction. The operator moves closing tube 14 in the distal direction to close upper jaw 42 by moving first actuator 104 in the distal direction.

Referring to FIGS. 2 and 3, closing tube 14 is shown to comprise a distal portion or section 18 and a proximal portion or section 16. Distal portion 18 of closing tube 14 is seen to have, preferably, an approximately rectangular,

cross-sectional shape with a left surface 20, a right surface 21 (hidden), an upper surface 22, and a lower surface 23 (hidden), with surfaces 22 and 23 being curved as shown. Tube 14 may have other geometric cross-sections such as circular, polygonal, oval, square and combinations thereof. Distal portion 18 of closing tube 14 further comprises distally extending upper arm 30 and lower arm 28 separated by a left slot 32 on left surface 20, and an identically shaped right slot 33 (hidden) on the right surface 21 (hidden). Proximal portion 16 of closing tube 14 slides freely inside of an elongated, tubular sleeve 12. Closing tube 14 and sleeve 12 are preferably constructed from round tubing in this embodiment, but may also be constructed from tubing having other geometric shapes such as, for example, rectangular, oval, polygonal, combinations thereof and the like. Although sleeve 12 may be made of a non-metallic material such as extruded polyethylene tubing, it is preferably metallic in order to contribute significantly to the bending stiffness of tube assembly 10. In this embodiment, tube assembly 10 is relatively long and thin (for example, fits through a 5 mm trocar) to enable the operator to use instrument 8 for endoscopic vessel harvesting as will be described.

Closing tube 14 is further seen to have a tab 26 formed into upper surface 22, which engages and opens upper jaw 42, as will be described for FIG. 9.

Still referring to FIGS. 2 and 3, upper jaw 42 is seen to have a plurality of upper teeth 58, and lower jaw 44 is seen to have a plurality of lower teeth 56, thus defining a tissue grasping region 57. Upper jaw 42 also includes an upper channel 54, and lower jaw 44 includes a lower channel 52, for the longitudinal movement of a cutting element 70 (see FIG. 4) partially contained inside of lower channel 52. A left fin 64 and a right fin 65 extend from lower jaw 44 to prevent cutting element 70 from cutting tissue when upper jaw 42 is in the open position. Upper jaw 42 further includes a blunt, upper tip 48 (also called a distal tip), and lower jaw 44 has a blunt, lower tip 46 (also called a distal tip). Upper tip 48 and lower tip 46 help the operator to funnel tissue into tissue grasping region 57. When upper jaw 42 is in the closed position, upper tip 48 and lower tip 46 form a V-shaped, dissecting tip 50 as shown in FIG. 3, which is useful for separating tissue layers as will be described. Upper arm 30 of closing tube 14 slides on a top surface 62 of upper jaw 42. Lower arm 28 of closing tube 14 slides on a bottom surface 60 of lower jaw 44. When lower jaw 44 is in the closed position as shown in FIG. 3, top surface 62 and bottom surface 60 are almost completely covered by closing tube 14. Tissue clamped between upper jaw 42 and lower jaw 44 extends laterally out of left slot 32 and right slot 33 (hidden) of closing tube 14, contacting a left lower edge 34 and a right lower edge 35 (see FIG. 4). A left flange 66 of upper jaw 42 separates tissue from a left upper edge 36 of upper arm 30. A right flange 67 (hidden) of upper jaw 42 separates tissue from a right upper edge 37 (hidden) of upper arm 30.

Now referring to FIG. 4, an exploded, isometric view of the distal portion of tube assembly 10 is shown. Upper jaw 42 is seen to have a distal portion 55 and a proximal portion 53 joined together at a hinge 49. Hinge 49 is sometimes referred to as a "living hinge" since it is a thin, flexible area of the injection molded, upper jaw 42. Upper jaw 42 also includes a cam follower 47 located near hinge 49, and a lip 43 located on top surface 62. Lower jaw 44 includes a distal portion 59 and a proximal portion 51 joined together at a cam 45. Cam follower 47 of upper jaw 42 rides against cam 45 of lower jaw 44.

As seen in FIG. 4, cutting element 70 comprises a proximal portion 80 (partially shown), a distal portion 78,



joined together at an offset **84**. Proximal portion **80** comprises a longitudinal element **76** and is attached to second actuator **102** shown in FIG. 1. Distal portion **78** and proximal portion **80** may be constructed from one piece of metal, or may be separate metallic elements joined together, for example, by a weld, mechanical connectors, rivets, pins, etc., and the like. Distal portion **78** is seen to have on the distal end a first blade **72** for cutting in the proximal direction and an opposed second blade **74** for cutting in the distal direction. The blades may be made as part of the distal portion **78** or mounted thereto by conventional methods such as welding, rivets, mechanical fasteners, etc. Lower jaw **44** contains cutting element **70** in lower channel **52** so that edge **82** of cutting element **70** is approximately flush with lower teeth **56**. Proximal portion **80** of cutting element **70** is slideably contained in a right channel **95** of a right retainer **91**, and in a left channel **96** (hidden) of a left retainer **90**. Left and right retainers, **90** and **91**, are also referred to together as a shaft having a proximal and a distal end. Closing tube **14** slides freely over left retainer **90** and right retainer **91**, which are mounted to handle assembly **100** of FIG. 1. Right retainer **91** and left retainer **90** are made from an electrically non-conductive material such as plastic, for example, in order to electrically isolate cutting element **70** from closing tube **14**. As a secondary electrical barrier, cutting element **70** may also be coated as desired with an insulative material. An example of a suitable coating for cutting element **70** is a thin sufficiently effective (for example, about 0.005 mm), vacuum deposited polymer well known in the art as parylene-n (also referred to as parylene), which is based on a high purity raw material called di-paraxylylene. Edge **82** of distal portion **78** of cutting element **70** functions as an electrode surface and comes into contact with tissue held between upper jaw **42** and lower jaw **44**. Edge **82** (also referred to as a second electrode surface) is not coated with parylene-n or any other insulating material, and is a conductive surface.

Still referring to FIG. 4, right retainer **91** is seen to include a right hook **93** extending distally from the distal end thereof for attachment to a right hook **99** extending proximally from proximal section **51** of lower jaw **44**. Left retainer **90** includes a left hook **92** for engagement with a left hook **98** extending proximally from the proximal section **51** lower jaw **44**. As a result, lower jaw **44** is stationary relative to cutting element **70** and closing tube **14**. The operator actuates second actuator **102** to move cutting element **70** in either longitudinal direction, and actuates first actuator **104** to move closing tube **104** in either longitudinal direction. Upper jaw **42** moves a short distance during opening and closing in the longitudinal directions due to operational engagement with closing tube **14**, as will be described.

Sleeve **12** fits concentrically over closing tube **14** and strengthens tube assembly **10** to resist bending as described earlier, and may be slidably mounted or fixedly mounted. Sleeve **12** also separates closing tube **14** from external structures rubbing against it that may impede its movement, such as tissue layers or a trocar seal if used with a trocar.

FIG. 5 is a cross-sectional view of the distal end of tube assembly **10** of FIG. 3, taken along View Lines 5—5. Left lower edge **34** (also referred to as a first conducting surface) and right lower edge **35** (also referred to as a second conducting surface) of lower arm **28** of closing tube **14** (also referred to as a first electrode) have a first polarity, for example, shown as positive. Spaced midway between left and right lower edges, **34** and **35**, is edge **82** of cutting element **70** contained in lower channel **52** of lower jaw **44**. Edge **82** has a second, opposite polarity, for example, shown

as negative. Edge **82** is laterally offset and electrical isolated from left and right lower edges, **34** and **35**. Therefore, edge **82** cannot electrically short to left and right lower edges, **34** and **35**, if there is no tissue clamped between upper jaw **42** and lower jaw **44**. However, bipolar electrosurgical current flows between edge **82** and left lower edge **34** through tissue clamped in a left compression zone **88** and bipolar electrosurgical current flows between edge **82** and right lower edge **35** through tissue clamped in a right compression zone **89**. Tissue is coagulated simultaneously in both left compression zone **88** and right compression zone **89**. Once this tissue is coagulated, tissue resistivity is increased and electrical conductivity is decreased. As a result, even though the operator may continue to supply bipolar electrosurgical energy to instrument **8** (by depressing the foot pedal control for the electrosurgical energy generator **6** of FIG. 1), it is believed that effectively no additional coagulation of tissue takes place. More significantly, there is no electrical pathway outside of the clamped jaws, **42** and **44**. Therefore, there is effectively no lateral thermal spread and coagulation of tissue outside of the jaws, **42** and **44**. Left upper edge **36** of closing tube **14** is electrically insulated from clamped tissue by left flange **66** of upper jaw **42**. Right upper edge **37** of upper arm **30** of closing tube **14** is electrically insulated from clamped tissue by right flange **67** of upper jaw **42**. First and second blades, **72** and **74**, of cutting element **70** (see FIG. 4) extend into upper channel **54**, to cut tissue contained between compression zones **88** and **89**. Upper channel **54** also serves as a vent for vapor to escape from upper jaw **42** during the application of RF energy.

As seen in FIG. 5, closing tube **14** has a substantially rectangular cross-section formed by upper surface **22**, lower surface **23**, left surface **20**, and right surface **21**. The upper and lower surfaces **22** and **23** are seen to have a slightly curved configuration in a preferred embodiment. The rectangular cross-sectional configuration is believed to have several advantages over, for example, a circular cross-sectional configuration: the rectangular cross-sectional configuration allows upper arm **30** and lower arm **28** to be stiffer so that deflection of upper arm **30** and lower arm **28** is minimized when tissue is clamped between upper jaw **42** and lower jaw **44**; the rectangular cross-sectional configuration allows better visualization of tissue structures on each side of closing tube **14**; the rectangular cross-sectional configuration has a smaller footprint on the clamped tissue and allows a higher pressure to be applied to tissue for a given closing force applied, thus aiding in the formation of a hemostatic weld of the tissue.

The closing tube **14** is multifunctional in that it moves upper jaw **42** between the open and closed positions, and it also serves as an electrical conductor, with left and right lower edges, **34** and **35**, being used as outer electrodes of the same polarity. Similarly, cutting element **70** is multifunctional in that it not only cuts tissue held between upper jaw **42** and lower jaw **44**, but edge **82** of cutting element **70** serves as an electrode having opposite polarity of closing tube **14**. By making closing tube **14** and cutting element **70** electrically active components, it is not necessary to provide separate, spaced apart, bipolar electrodes in lower jaw **44**. Consequently, the overall width of lower jaw **44** is significantly smaller than would be if separate electrodes of opposite polarity were mounted in lower jaw **44**. This enables the aforementioned benefits of a smaller footprint on the tissue. In addition, the number of components and the overall cost to manufacture the instrument is reduced by the multifunctional of closing tube **14** and cutting element **70**.

Because instrument **8** incorporates offset electrodes technology and the tissue reaches a high coagulation temperature

only very briefly, tissue does not char or burn as may occur when using conventional bipolar instruments. Nevertheless, a small amount of sticking of tissue to electrode surfaces in instrument **8** may still occur. In instrument **8**, closing tube **14** moves longitudinally (i.e., proximally or distally) for each time upper jaw **42** is opened or closed, thus causing the active electrical surfaces, right lower edge **35** and left lower edge **34**, to move relative to the stationary tissue held between upper jaw **42** and lower jaw **44**. This allows any tissue that may be adhering to right and lower edges, **34** and **35**, after the application of energy and the coagulation of tissue, to break free. Similarly, each time the operator actuates cutting element **70** in either the proximal or distal direction, the electrically active surface, edge **82** of cutting element **70**, breaks free from adhering tissue. All electrically active surfaces in instrument **8** are wiped against the tissue clamped for each cycle of operation (clamp/coagulate/cut/open), thus helping to keep those surfaces clean and electrically conductive. In addition, when the operator opens upper jaw **42**, the ends of the treated tissue are more likely to fall freely from the jaws than if using conventional bipolar devices, and it is not necessary to excessively manipulate instrument **8** to remove the tissue.

FIG. 6 is an exploded, isometric view of handle assembly **100**, which preferably has an "in-line" style (as opposed to pistol-grip, etc.) in this embodiment, but is not restricted to this style. A right handle shell **108** includes a plurality of bosses **160** for assembly to a matching number of gripper pins **161** on left handle shell **110**. Right and left handle shells, **108** and **110**, are preferably injection molded from a rigid, conventional, biocompatible plastic such as polycarbonate and the like. The shells **108** and **110** support the following components: first actuator **104**, second actuator **102**, power cord **106**, a divider **112**, a bidirectional spring **114**, and a sequencing lever **116** (also referred to as a sequencing element or operational sequencing element).

As described for FIG. 1, first actuator **104** is slidably mounted in handle assembly **100** and controls the longitudinal movement of closing tube **14** for opening and closing upper jaw **42** (FIG. 2). When the operator moves first actuator **104** distally from an open position to a distal closed position, upper jaw **42** closes.

When the operator moves first actuator **104** proximally from the closed position to the open position, upper jaw **42** opens. First actuator **104** does not have a return spring or any other means for providing a biasing force to either the extended or open position in this preferred embodiment, although it is possible and within the scope of this invention to do so.

Second actuator **102** controls the longitudinal movement of cutting element **70**. When the operator moves second actuator **102** in the proximal direction from a central position to a proximal position, first blade **72** (FIG. 4) of cutting element **70** moves proximally and cuts through tissue clamped between upper jaw **42** and lower jaw **44** within tissue grasping region **57** (FIG. 2). When the operator releases second actuator **102**, it moves from the proximal position back to the central position due to the biasing force provided by bidirectional spring **114** (preferably a helical coil spring). As cutting element **70** moves distally from the proximal position to the central position, second blade **74** (FIG. 4) of cutting element **70** cuts a second time through tissue clamped between upper jaw **42** and lower jaw **44**. When the operator moves second actuator **104** in the distal direction from the central position to a distal position, cutting element **70** extends distally so that second blade **74** (FIG. 4) is exposed to tissue adjacent to dissecting tip **50**,

allowing the operator to separate tissue layers and cut through tissue distally adjacent to dissecting tip **50** as the operator advances instrument **8** in the distal direction. When the operator releases second actuator **102**, cutting element **70** moves proximally and again returns to the central position due to the biasing force provided by bi-directional spring **114**. A biasing force is provided for cutting element **70** in this embodiment so that first and second cutting blades, **72** and **74**, are safely contained between left and right fins, **64** and **65**, of lower jaw **44** when the operator is not actuating second actuator **102**. In another embodiment of the present invention, bidirectional spring **114** may be eliminated so that movement of the cutting element **14** is possible only when the operator moves second actuator **104**.

Still referring to FIG. 6, second actuator **102** is seen to have a frame **103** that supports bidirectional spring **114**, which is a helical coil wire compression spring in a preferred embodiment. If desired, other types of conventional springs may be used such as leaf springs, etc. A rail **132** on frame **103** of second actuator **102** rides inside of a right track **130** of right handle shell **108**, so that bidirectional spring **114** is trapped between a first stop **126** and a second stop **128** of right handle shell **108**. Second actuator **102** includes a mount member **136** having a projection **137** for insertion into and engagement with a notch **154** on cutting element **70**, so that longitudinal translation of second actuator **104** causes an equal longitudinal translation of cutting element **70** in the same direction. First actuator **104** is seen to have a bar slider **163**, which rides on a left track **131** (hidden) on the inside of left handle shell **110**. First actuator **104** also has a closing block **164** that contains a pair of slots **165** (hidden) for receiving a pair of tabs **172** extending radially on the proximal end of closing tube **14**, so that longitudinal translation of first actuator **102** causes an equal longitudinal translation of closing tube **14** in the same direction. Closing block **164** is supported and guided also by a right shelf **162** in right handle shell **108** and a left shelf **155** (hidden) in left handle shell **110**. First actuator **104** and second actuator **102** are separated by divider **112** having a top fin **142** to help prevent the operator from actuating first and second actuators, **104** and **102**, at the same time. Divider **112** also provides a tactile, positional reference for the operator to know the relative positions of first and second actuators, **104** and **102**, without looking at them. A first tab **138** and a second tab **140** extending off opposite ends of divider **112** mount divider **112** to a first support **146** and a second support **148**, respectively, of right handle shell **108**. A yoke **144** on divider **112** mounts onto a right retaining fin **150** of right handle shell **108** and a similar, left retaining fin **151** (hidden) on the inside of left handle shell **110**. First actuator **104**, second actuator **102**, and divider **112** are preferably injection molded from a rigid, biocompatible plastic such as polycarbonate, although many other conventional materials may also be used.

Still referring to FIG. 6, an optional, although preferred, sequencing lever **116** (also referred to as a sequencing element) ensures the proper sequence of operation of first and second actuators, **104** and **102**. More specifically, sequencing lever **116** locks out second actuator **102** from moving to the proximal position (moving cutting element **70** to the proximal position) unless first actuator **104** is at the closed position (for when upper jaw **42** is closed and tissue is clamped). When tissue has been clamped for a period of time and electrosurgically coagulated, the tissue becomes less elastic and clamping force relaxes. To sever the coagulated tissue hemostatically, however, it is important that the coagulated tissue continue to be held firmly between upper

and lower jaws, **104** and **102**, so that cutting element **70** cuts through the middle of the coagulated tissue. This leaves an equal margin of coagulated tissue on each of the severed ends of the tissue so that the transection is hemostatic. Sequencing lever **116** also prevents first and second blades, **72** and **74**, from being exposed to tissue in tissue grasping region **57** (FIG. 2) between upper and lower jaws, **42** and **44**, while the operator positions instrument **8** prior to clamping, thus preventing inadvertent cutting of the tissue. Sequencing lever **116** also prevents first actuator **104** from moving from the closed position to the open position (to open upper jaw **42**) unless second actuator **102** is safely in the distal or central positions and first and second blades, **72** and **74**, are not in tissue clamping region **57**. Sequencing lever **116** is preferably made of stainless steel, although it may be injection molded from a rigid, high strength plastic or other conventional materials. Sequencing lever **116** has a hole **168** that mounts pivotably onto post **166** of right handle shell **108**, and a slot **170** for operational engagement with a first pin **134** extending off of frame **103** of second actuator **102**.

FIG. 6 depicts a portion of power cord **106** having a strain reliever **174** that inserts between a pair of bosses **160** in right handle shell **108**. Power cord **106** also includes an electrically insulated, first conductor **118** terminating with a first connector **122** for electrical attachment to cutting element **70**, and an electrically insulated, second conductor **120** terminating with a second connector **124** for electrical attachment to closing tube **14**. First and second connectors, **122** and **124**, are shown in this embodiment to be configured for quick assembly, although various other types of connectors well known in the art or soldering and other conventional mounting techniques may be used in this application. The conductors are made from conventional conducting materials including copper wire, aluminum wire and the like and equivalents thereof.

Still referring to FIG. 6, it can be seen that handle assembly **100** retains tube assembly **10** as follows: left and right retainers, **90** and **91**, have a pair of opposing recesses **152** for staking to left and right retaining fins, **151** (hidden) and **150**. Sleeve **12** has a pair of opposing slits **156** (one is hidden) for retention in a right cradle **158** of right handle shell **108** and a left cradle **157** (hidden) of left handle shell **110**. A holder **159** supports sleeve **12**.

Now referring to FIG. 7, a side view of handle assembly **100** without left shell **110** reveals the orientation of sequencing lever **116** for when first actuator **104**, attached to closing tube **14**, is in the open position and second actuator **102** (substantially hidden by fin **142**) is in the central position. First pin **134**, which extends from frame **103** of second actuator **104** rests in slot **170** of sequencing lever **116**. Closing block **164** of first actuator **104** prevents rotation of sequencing lever **116** about post **166**, thereby causing slot **170** to be inclined relative to the longitudinal axis of handle assembly **100**, and preventing movement in the proximal (right) direction of second actuator **102**. As FIG. 7 shows, a lever end **117** cannot move in the clockwise direction until a closing block corner **169** is distal to it, thus preventing movement of second actuator **104** in the distal direction. Bi-directional spring **114** is slightly compressed within frame **103**, but does not exert a biasing force on second actuator **102** in either longitudinal direction.

FIG. 8 is a top view of handle assembly **100** showing the positions of first actuator **104** and second actuator **102** (separated by fin **142**) corresponding with FIG. 7.

FIG. 9 is a cross-sectional view of the distal portion of tube assembly **10**, and corresponds with FIGS. 7 and 8.

Closing tube **14** is in the open position so that tab **26** engages a lip **43** of upper jaw **42**, causing a follower **47** of upper jaw **42** to ride up on a cam **45** of lower jaw **44**, thus causing upper jaw **42** to flex at a hinge **49** of upper jaw **42** to the open position. Cutting element **70** is in the central position with first blade **72** and second blade **74** protected by left fin **64** (removed in this view) and right fin **65**. When upper jaw **42** closes against lower jaw **44**, cam **45** and left and right fins, **64** and **65**, contain tissue to be clamped in tissue grasping region **57**, ensuring that tissue to be treated does not squeeze out the distal end of the upper and lower jaws, **42** and **44**, as may occur in other surgical grasping instruments. The wiping action of follower **47** against cam **45** also ensures that tissue is not pinched in between upper and lower jaws, **42** and **44**, such as may occur in other surgical grasping instruments.

FIG. 10 is a side view of handle assembly **100** with left shell **110** removed to reveal the position of sequencing lever **116** for when first actuator **104** is in the closed position and second actuator **102** (substantially hidden by fin **142**) is in the central position. Closing block corner **169** of closing block **164** is distal to lever end **117**, thus allowing rotation of sequencing lever **116** about post **166**, and proximal translation of second actuator **102**. As first pin **134** extending off frame **103** translates proximally, slot **170** moves from the steeply inclined orientation shown in FIG. 10 to a less inclined position as shown in FIG. 13. Bi-directional spring **114** is in the same configuration for FIG. 10 as for FIG. 7, and is not providing a biasing force in either longitudinal direction to second actuator **104**.

FIG. 11 corresponds with FIG. 10 and shows a top view of handle assembly **100** for when first actuator **104** is in the closed position and second actuator **102** is in the central position, with fin **142** between first actuator **104** and second actuator **102**.

FIG. 12 is a sectional view of the distal portion of tube assembly **10** corresponding with FIGS. 10 and 11. Upper jaw **42** is in the closed position and tab **26** of closing tube **14** is separated from lip **43** of upper jaw **42**. Follower **47** of upper jaw **42** abuts cam **45** of lower jaw **44** so that upper jaw **42** fits tightly against lower jaw **44** with very minimal air gaps there between. This ensures that tissue may be securely clamped during coagulation and cutting, and provides an additional electrical barrier between cutting element **70** and closing tube **14**. First blade **72** and second blade **74** are in the central position and safely separated from tissue that may be clamped between upper jaw **42** and lower jaw **44**. Dissecting tip **50** may be used in this configuration as a blunt dissector and tissue layer separator without cutting.

FIG. 13 is a side view of handle assembly **100** with left shell **110** removed to reveal the position of sequencing lever **116** for when first actuator **104** is in the closed position and second actuator **102** is in the proximal position. Fin **142** provides a tactile reference for the operator to feel the change of position for first and second actuators, **104** and **102**. Closing block corner **169** of closing block **164** is distal to lever end **117** so that sequencing lever **116** rotates about post **166** when first pin **134** translates proximally within slot **170**. Bi-directional spring **114** is compressed between frame **103** of second actuator **102** and second stop **128** of handle shell **108**, thus providing a biasing force in the distal direction (and urging second actuator **104** to move from the proximal position to the central position.)

FIG. 14 is a top view of handle assembly **100** corresponding with FIG. 13 for when first actuator **104** is in the closed position and second actuator **102** is in the proximal position. Fin **142** separates first and second actuators, **104** and **102**.

FIG. 15 is a sectional view of the distal portion of tube assembly 10 corresponding to FIGS. 13 and 14. Upper jaw 42 is in the closed position with closing tube 14 substantially covering upper jaw 42 and lower jaw 44. Cutting element 70 is shown in the proximal position with first blade 72 having made a first cut through tissue that may have been clamped between upper and lower jaws, 42 and 44. Second blade 74 is positioned to make a second pass through the tissue upon release of second actuator 104 (FIG. 13).

FIG. 16 is a side view of handle assembly 100 with left handle shell 110 removed and shows the position of sequencing lever 116 for when first actuator 104 is in the closed position and second actuator 102 (substantially hidden by fin 142) is in the distal position. Closing block corner 169 of closing block 164 is again distal to lever end 117, although this is not necessary for pin 134 to move in the distal direction inside of slot 170 of sequencing lever 116. Bi-directional spring 114 is compressed between first stop 126 of right handle shell 108 and frame 103 of second actuator 104, thus providing a biasing force to second actuator 104 in the proximal direction.

FIG. 17 is a top view of handle assembly 100 corresponding with FIG. 16, and shows first actuator 104 in the closed position. Fin 142 separates first actuator 104 from second actuator 102, which is in the distal position. The operator must hold second actuator 104 in the distal position due to the biasing force, which bi-directional spring 114 provides.

FIG. 18 is a sectional view of the distal portion of tube assembly 10, corresponding with FIGS. 16 and 17. Closing tube 14 surrounds upper jaw 42 and lower jaw 44 in the closed position. Cutting element 70 is in the distal position so that second blade 74 extends partially into the V-shape opening of dissecting tip 50 and is able to sever tissue that would be distally adjacent to dissecting tip 50. Second blade 72 is still protected within upper jaw 42 and lower jaw 44.

FIG. 19 is a isometric view of instrument 8 being used for a surgical procedure in combination with a surgical retractor 200 for endoscopically harvesting a vessel 224 from a surgical patient 220 for use in a coronary artery bypass graft (CABG) surgical procedure. Retractor 200 and its method of use are disclosed in U.S. Pat. Nos. 5,928,138 and 5,928,135 and are hereby incorporated herein for reference. Retractor 200 comprises a grip 204 attached to the proximal end of an endoscopic shaft 208, which may be inserted into an incision 226. A spoon element 206 is attached to the distal end of endoscopic shaft 208. The operator manipulates retractor 200 to advance a spoon shaped, working head 206 along vessel 224, separating tissue from vessel 224 and providing a working space for accessing and visualizing vessel 224 and a plurality of side branches 222. A port 202 provides access for an endoscope (not shown) for visualization within working head 206. A nozzle 210 may connect to a low pressure, carbon dioxide gas source for clearing away vapor and smoke from within the working space inside working head 206. Tube assembly 10 of instrument 8 inserts through incision 226 underneath shaft 208 of retractor 200. Tube assembly 10 could also be inserted through a port in an endoscope or retractor or endoscopic vein harvesting instrument. The operator manipulates instrument 8 within the working space inside working head 206 to dissect, clamp, coagulate, and cut tissue as described for FIGS. 7-18. In particular, side branches 222 are coagulated and cut without damaging harvested vessel 224. The length of tube assembly 10 may vary, but preferably is long enough for handle assembly 100 to be proximal to the endoscope inserts into port 202 while tube assembly 10 is inserted far enough into patient 220 to access the working space within working head

206. Instrument 8 may be used with other conventional retractors and vein harvesting instruments.

Instrument 8 is especially suited for vessel harvesting as described for FIG. 19, but is not limited to only this surgical procedure. Instrument 8 may also be used to dissect, clamp, coagulate, and cut tissues during numerous other types of endoscopic and open surgical procedures. Instrument 8, as described in the present embodiment, is intended for single patient use. Instrument 8 may be constructed, however, from materials and using techniques, allowing re sterilization and reuse on more than one surgical patient.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention.

What is claimed is:

1. A bipolar electrosurgical instrument comprising:

- a handle, said handle having a proximal end, a distal end, a top surface and an interior cavity;
- a first conductor and a second conductor mounted to said handle;
- a shaft having a distal end, a proximal end, a longitudinal axis extending therebetween, said proximal end of said shaft mounted to said handle;
- a closing tube slidably mounted to said shaft, said closing tube having a proximal end, a distal end, a longitudinal axis, and a lumen therethrough;
- a pair of opposed arms extending distally from the distal end of said closing tube, said arms spaced laterally apart;
- a first electrode surface on one of said arms, said electrode surface in electrical contact with said first conductor, said electrode surface having a first polarity;
- a first or lower jaw member mounted in the distal end of said closing tube, said first or lower jaw having a proximal end and a distal end an outer surface and an inner surface, said proximal end of said first or lower jaw mounted to the distal end of the shaft;
- an opposed second or upper jaw member mounted in the distal end of the closing tube, said second or upper jaw having a proximal end and a distal end, an outer surface and an inner surface, said second or upper jaw moveable relative to said lower jaw from a closed position to an open position;
- an elongated member slidably mounted in said shaft, said member having a proximal end and a distal end, said proximal end movable in said jaws mounted in one of said upper and lower arms, said elongated element having a second electrode surface positioned substantially parallel to and laterally offset from said first electrode surface, said second electrode electrically connected to said second conductor and having a second electrical polarity that is opposite of said first electrical polarity, so that bipolar electrosurgical energy may be conducted through tissue located between said first electrode surface and said second electrode surface;
- a first actuator mounted in the handle, said first actuator connected to the proximal end of the closing tube, wherein movement of the first actuator causes the sliding tube to move longitudinally; and,
- a second actuator mounted in the handle, the second actuator connected to the proximal end of the elongated member, wherein movement of the second actuator causes the elongated member to move longitudinally.

2. The instrument of claim 1, wherein the arms comprise an extension of the distal end of the sliding tube formed by a pair of opposed slots in the extension.

3. The instrument of claim 1 wherein said first electrode surface contacts tissue approximated between said upper and lower jaw members when the upper jaw member is in the closed position, and the first conducting electrode is spaced apart from tissue approximated between said upper and lower jaw members when said upper jaw member is in said open position.

4. The bipolar electrosurgical instrument of claim 2 wherein said upper and lower arms substantially enclose said upper and lower jaw members when said upper jaw is in said closed position, so that tissue is positioned within said opposed slots when tissue is approximated between said upper and lower jaw members.

5. The bipolar electrosurgical instrument of claim 1 wherein said upper and lower arms together have an approximately rectangular cross-sectional shape.

6. The bipolar electrosurgical instrument of claim 1 wherein said upper arm is shorter than said lower arm.

7. The bipolar electrosurgical instrument of claim 1 further comprising a first longitudinal channel in said lower jaw and a second longitudinal channel in said upper jaw member, said first and second channels forming a cutting path when said upper jaw member is in said closed position.

8. The instrument of claim 7, additionally comprising a cutting element longitudinally moveable within said cutting path to cut tissue approximated between said upper and lower jaws, said cutting element mounted to the distal end of the elongated member.

9. The bipolar electrosurgical instrument of claim 8, wherein said cutting element comprises a cutting blade.

10. The bipolar electrosurgical instrument of claim 1 wherein said closing tube further comprises a second conducting surface substantially parallel to and laterally spaced apart from said first conducting surface, and said second conducting surface has the same electrical polarity as said first conducting surface, and said second electrode surface of said longitudinal element is spaced laterally between said first and second conducting surfaces, so that bipolar electrosurgical energy may be conducted through tissue approximated between said first conducting surface and said second electrode surface, and between said second conducting surface and said second electrode surface, and said cutting element is movable from said distal position to said proximal position to longitudinally cut tissue approximated between said first and second conducting surfaces.

11. The instrument of claim 1, wherein the closing tube comprises an electrically conductive material.

12. The instrument of claim 1 wherein the arms comprise an electrically conductive material.

13. The instrument of claim 1 wherein the lower jaw comprises an electrically non-conducting material.

14. The instrument of claim 1 wherein the upper jaw comprises an electrically non-conductive material.

15. The instrument of claim 1 wherein both the upper and lower jaws comprise electrically non-conducting material.

16. The instrument of claim 1 wherein the jaw members comprise tissue engaging teeth extending out from the inner surface of each jaw member.

17. The combination of an electrosurgical generator and a bipolar electrosurgical instrument, said combination comprising:

- I. A bipolar electrosurgical instrument, said instrument comprising:
  - a handle, said handle having a proximal end, a distal end, a top surface and an interior cavity;

a first conductor and a second conductor mounted to said handle;

a shaft having a distal end, a proximal end, a longitudinal axis extending therebetween, said proximal end of said shaft mounted to said handle;

a closing tube slidably mounted to said shaft, said closing tube comprising a proximal end, a distal end, a longitudinal axis, and a lumen therethrough;

a pair of opposed arms extending distally from the distal end of said closing tube, said arms spaced laterally apart;

a first electrode surface on one of said arms, said electrode surface in electrical contact with the first conductor, said electrode surface having a first polarity;

a first or lower jaw member mounted in the distal end of said closing tube, said first or lower jaw having a proximal end and a distal end an outer surface and an inner surface, said proximal end of said first or lower jaw mounted to the distal end of the shaft;

an opposing second or upper jaw member mounted in the distal end of the closing tube, said second or upper jaw having proximal end and a distal end, an outer surface and an inner surface, said second or upper jaw moveable relative to said lower jaw from a closed position to an open position;

an elongated member slidably mounted in said shaft, said member having a proximal end and a distal end, said proximal end movable in said jaw members and electrically isolated from said closing tube, said elongated member having a second electrode surface positioned substantially parallel to and laterally offset from said first electrode surface, said second electrode surface electrically connected to said second conductor and having a second electrical polarity that is opposite of said first electrical polarity, so that bipolar electrosurgical energy may be conducted through tissue located between said first electrode surface and said second electrode surface;

a first actuator mounted in the handle, said first actuator connected to the proximal end of the closing tube, wherein movement of the first actuator causes the sliding tube to move longitudinally; and,

a second actuator mounted in the handle, the second actuator connected to the proximal end of the elongated member, wherein movement of the second actuator causes the elongated member to move longitudinally; and,

II. a bipolar surgical generator, said generator comprising a first output having a first polarity and a second output having a second polarity, wherein said first and second conductors are electrically connected to said first and second outputs.

18. A method of coagulating tissue, said method comprising the steps of:

providing a bipolar electrosurgical surgical instrument, said bipolar electrosurgical instrument comprising:

a handle, said handle having a proximal end, a distal end, a top surface and an interior cavity;

a first conductor and a second conductor mounted to said handle;

a shaft having a distal end, a proximal end, a longitudinal axis extending therebetween, said proximal end of said shaft mounted to said handle;

a closing tube slidably mounted to said shaft, said closing tube having a proximal end, a distal end, a longitudinal axis, and a lumen therethrough;

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a pair of opposed arms extending distally from the distal end of said closing tube, said arms spaced laterally apart;

a first electrode surface on one of said arms, said electrode surface in electrical contact with said first conductor, said electrode surface having a first polarity;

a first or lower jaw mounted to the distal end of said closing tube, said first or lower jaw having a proximal end and a distal end an outer surface and an inner surface, said proximal end of said first or lower jaw mounted to the distal end of the shaft;

an opposed second or upper jaw member mounted in the distal end of the closing tube, said second or upper jaw having a proximal end and a distal end, an outer surface and an inner surface, said second or upper jaw moveable relative to said lower jaw from a closed position to an open position;

an elongated member slidably mounted in said shaft, said member having a proximal end and a distal end, said proximal end movable in said jaws mounted in one of said upper and lower arms, said longitudinal element having a second electrode surface positioned substantially parallel to and laterally offset from said first electrode surface, said second electrode electrically connected to said second conductor and having a second electrical polarity that is opposite of said first electrical polarity, so that bipolar electrosurgical energy may be conducted through tissue located between said first electrode surface and said second electrode surface;

a first actuator mounted in the handle, said first actuator connected to the proximal end of the closing tube,

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wherein movement of the first actuator causes the sliding tube to move longitudinally; and,

a second actuator mounted in the handle, the second actuator connected to the proximal end of the elongated member, wherein movement of the second actuator causes the elongated member to move longitudinally, electrically connecting said first and second conductors to a bipolar surgical generator;

engaging tissue between said jaw members such that said tissue is between the inner surfaces of said first and second jaw members;

closing said jaw members about said tissue such that said tissue is engaged by the inner surfaces of said jaw members; and,

causing a sufficient amount of electrical energy from said generator to move across the tissue between the first and second electrode surfaces effective to coagulate the tissue.

**19.** The method of claim **18** additionally comprising the step of cutting the tissue between the jaws after the tissue has been coagulated.

**20.** The method of claim **19**, wherein the instrument comprises a cutting element mounted to the distal end of the elongated member, and the first and second jaw members have first and second longitudinal grooves, respectively, and wherein the cutting element is movable slidably in the grooves between the jaw members when the second jaw member is in a closed position.

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